Winter Conditions

From October through March, the river cools, daylength shortens, and aquatic plants and algae diminish. During these months, very few dissolved oxygen violations occurred, pH violations decreased substantially, and turbidity was lower compared with conditions in April through September.

Percent of time Kiona exceeded threshold value, October 1 thru March 31

	2005	2006	2007
DO < 8.0 mg/L	1	3	0
pH > 8.5 units	13	11	7
Temperature > 21 °C	0	0	0
Turbidity > 10 FNU	2	21	29

Temperature

In addition to photosynthesis, dissolved oxygen also is affected by temperature. Metabolic activity of stream biota, including photosynthesis and respiration, is often higher at higher water temperatures. Temperature also affects the solubility of dissolved oxygen — warmer water can physically hold less dissolved oxygen than colder water.

At Kiona, the water temperature at which dissolved oxygen in the river fell below 8 mg/L differed considerably between years (see table to the right). The differences were largely a reflection of the varying amounts of aerobic organisms in the river (plants, algae, bacteria, insects, fish, etc.) not due to the differences in the solubility of dissolved oxygen at varying temperatures. Based solely on the solubility of oxygen in water at a typical barometric pressure for this site and excluding biological activity, water temperature would have to exceed 26 ºC for dissolved oxygen to fall below 8 mg/L.

Temperature at which dissolved oxygen conc. fell below 8 mg/L

Year	Water temperature (ºC)	(ºF)
2004	18.1	64.6
2005	15.4	59.7
2006	20.2	68.4
2007	17.6	63.7
4-year average	18.8	65.8

Future Management Considerations

Aquatic plant biomass decreased 97% between 2005 and 2006 in the Kiona reach, to levels some would consider as healthy. Yet violations of the state dissolved oxygen and pH standards still occurred. Why? The role of algae (growing along river margins and on plants) in this reach was not assessed but could be part of the answer.

Reaches and years with the most abundant aquatic growth had the lowest dissolved oxygen conditions but this linkage was less direct for pH, suggesting that: (1) pH is strongly linked to other factors besides aquatic plant growth; and (2) improving pH conditions might be even more challenging than improving dissolved oxygen conditions in the lower Yakima River.

Conclusions

Dissolved oxygen and pH conditions were variable throughout the lower 116 miles of the Yakima River. The dissolved oxygen concentrations tended to be lower in reaches having abundant aquatic plants and algae, whereas pH was high intermittently throughout the river, in part due to differences in buffering capacity. Despite having the highest nutrient concentrations, the Mabton reach had the fewest dissolved oxygen and pH violations because other factors, such as suitable substrate or light availability, limited aquatic plant and algal growth. Compared with 2005, dissolved oxygen conditions in the Kiona reach improved in 2006 and 2007 when plant abundance decreased from higher turbidity and greater water depths during the spring snowmelt period, limiting light availability for the plant growth. In addition to aquatic plant abundance, temperature also influenced dissolved oxygen concentrations during the four years studied: as temperature increased, dissolved oxygen concentrations decreased, primarily due to increasing metabolic rates of biota occurring at higher water temperatures.

Dissolved Oxygen and pH in the Lower Yakima River

South Yakima Conservation District

April 2008

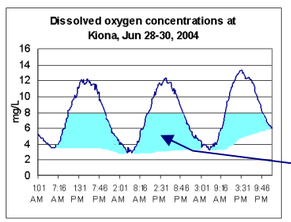
Benton Conservation District

The U.S. Geological Survey, South Yakima Conservation District, and Benton Conservation District worked together to study the Yakima River from 2004 through 2007 to learn more about nutrients, algae, rooted aquatic plants, and dissolved oxygen and pH conditions in the river. Why the concern? Excessive plant and algal growth in rivers may result in insufficient dissolved oxygen and excessive pH levels due to photosynthesis. Aquatic plants had become visibly more abundant since 2002. Were aquatic plants and algae causing problems with dissolved oxygen and pH in the lower Yakima River?

The opinions and conclusions expressed in this flyer are those of the conservation districts, not the U.S. Geological Survey. The final project report from USGS is not yet completed. This information is being provided before the final report because of timing constraints from the grant funding which paid for this work.

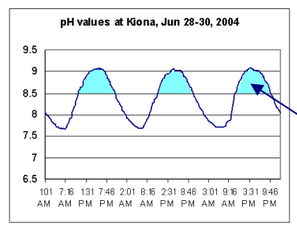
Introduction

Dissolved oxygen and pH are important indicators of a river's health. According to state standards, in the lower Yakima River dissolved oxygen should not be less than 8 milligrams per liter (mg/L) and pH should not exceed 8.5 units or fall below 6.5 units. Dissolved oxygen concentrations are a function of water temperature, barometric pressure, aeration, and biological activity. Plant photosynthesis during the day increases dissolved oxygen while respiration by many organisms, including plants, microbes, invertebrates, and fish consume oxygen. Similarly, pH is affected by the metabolism of river organisms through their use and production of carbon dioxide. This produces a daily fluctuation in dissolved oxygen and pH. To capture these fluctuations, continuous water quality monitors which recorded data every 15 minutes were deployed in the river at various times and locations from 2004 through 2007.



Bacteria, fish, and insects consume O_2 all the time. Algae & plants produce O_2 during the day but consume it at night.

Violations. State standard: not less than 8 mg/L dissolved oxygen.

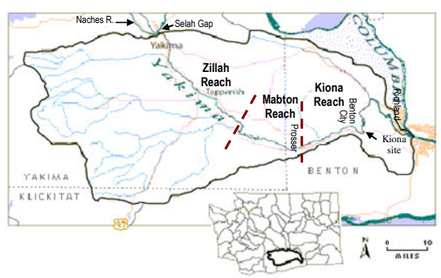


Algae & plants use CO_2 during the day, which raises the pH.

Violations. State standard: pH no more than 8.5

Patterns in Dissolved Oxygen and pH Conditions in 2004

In 2004, two monitors were deployed at nine sites in the lower Yakima River and one site in the Naches River from April to early October for 1-2 week periods, generally 3-4 times at each site. A third monitor in the Kiona reach, near Benton City, collected data from April 2004 through September 2007.



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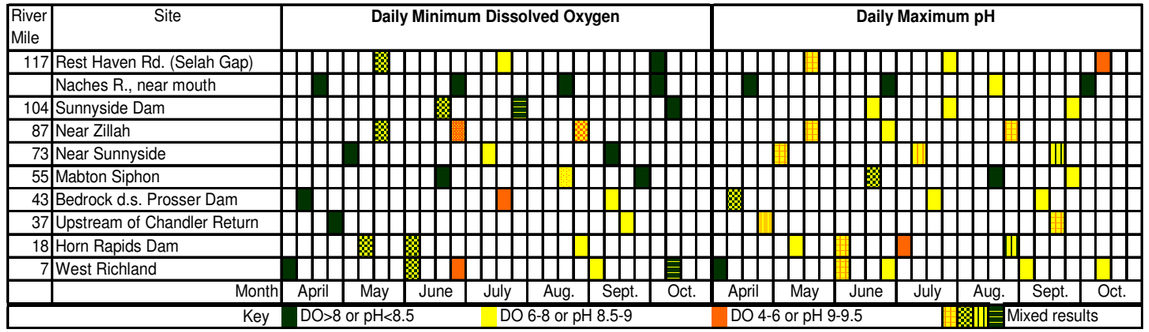
Spatial and Seasonal Patterns in 2004



Spatial Patterns

What spatial patterns emerged from the 10 sites measured intermittently in 2004? Periodic episodes of low dissolved oxygen concentrations generally corresponded to patterns in aquatic plant and algal abundance among the reaches but patterns in pH did not. The dissolved oxygen conditions were worse in the Zillah and Kiona reaches, where algae and rooted aquatic plants, respectively, were abundant. The fewest dissolved oxygen and pH violations occurred in the Mabton reach, with sparse aquatic plant growth. The highest (worst) pH levels occurred in the Kiona reach and at Selah Gap (the uppermost site in the study). The relatively low alkalinity at Selah Gap contributed to the high pH; low alkalinity waters afford less buffering capacity to changes in pH.

Seasonal Patterns

In April, dissolved oxygen concentrations met the state standard at each site monitored. In May through September, however, the daily minimum dissolved oxygen concentration was frequently 6-8 milligrams per liter (mg/L). Minimum values at three sites (RM 87, 43, and 7) were 4-6 mg/L in the late June to late August period. Conditions greatly improved by October. In contrast, the pH did not appear to have such a distinct seasonal pattern. None of the sites met the state pH standard throughout the entire season, including the Naches River. The Yakima River at Selah Gap and the Naches River had relatively low alkalinity which provides less buffering capacity and contributes to the high pH fluctuations. The most common daily maximum pH values ranged from 8.5 to 9.0, although values above 9.0 occurred at seven out of the ten sites monitored.

Patterns in Three Reaches in 2005

In 2005 (a drought year), monitors were deployed at one site in each of the three major reaches in the lower Yakima River (Zillah, Mabton, and Kiona) from March through September. The spatial patterns in 2005 were similar to the patterns from intermittent deployments in 2004. The Mabton site had the lowest percentage of time with dissolved oxygen or pH violations. The Zillah and Kiona sites had similar percentages of time with dissolved oxygen violations but the minimum values were often lower (3-4 mg/L) at the Kiona site than at the Zillah site (5-6 mg/L). The Kiona site had the highest percentage of time with pH violations, although the Zillah site also did not meet the pH standard nearly half of the time. Despite the highly abundant rooted aquatic plant growth in the Kiona reach during 2005, dissolved oxygen conditions were similar in 2004 and 2005 (see next page).

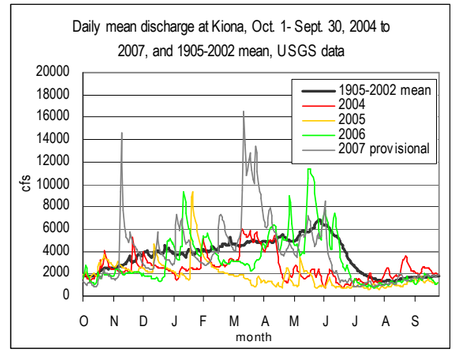
Percent of time the river exceeded a threshold value at three sites, early March to Sept 30, 2005.

	DO < 8.0 mg/L	pH > 8.5 std units	Temperature > 21.0 deg C	Turbidity >10 FNU	Turbidity >20 FNU
Near Zillah	31	45	23	6	1
Near Mabton	12	25	35	4	0
At Kiona	35	62	40	2	0

The patterns in dissolved oxygen and pH among the three reaches did not correspond to water-column nutrient concentrations. Nutrients in 2004 and 2005 were relatively low in the Zillah reach, highest in the Mabton reach, and high in the Kiona reach. Why didn't the reach with the highest nutrient concentrations have the worst dissolved oxygen and pH conditions? As discussed in more detail in the other handouts, other habitat factors limited plant and algal growth, despite adequate-to-abundant nutrient concentrations.

draft

Conditions in the Kiona Reach, 2004-2007



One monitor was deployed at Kiona almost continuously from April 2004 to September 2007, providing very powerful data over a wide range of hydrologic conditions and aquatic plant abundance. Flows were below average in 2004, far below average in the drought of 2005, average in 2006, and above average in 2007. Prolonged high flows during spring occurred in 2006 and 2007, increasing water depth and turbidity in the river (see table, below). As a result, less light reached the river bed and aquatic plant abundance decreased by 92-97%, compared with 2005.

Conditions in Years with Abundant Growth

Daily minimum dissolved oxygen concentrations were lowest during 2004 and 2005, as low as 3 mg/L, a near-lethal concentration for sensitive species such as salmon, on seven days during these two summers. Daily minimum dissolved oxygen concentrations generally were above the state standard in March, decreasing to their lowest values intermittently during late May 2005, late June 2004, and July and August 2004 and 2005, and not consistently meeting the state standard until mid-October.

Conditions in Years with Decreased Growth

The dissolved oxygen conditions improved in 2006 and 2007, when aquatic plant biomass was reduced substantially. Daily minimum concentrations generally met the state standard until mid-June. Also, once violations began to occur, the minimum values were not as low in 2006-07 as in 2004-05. The percentage of time the state standard was not met decreased from 37% and 35% in 2004 and 2005 to 18% and 23% in 2006 and 2007 (see table, right). In contrast, the percentages of time the pH standard was not met were similar in 2004, 2006, and 2007, worsening substantially only in 2005. In 2005, there were also more days when the pH exceeded 9.5 than in other years.

Select conditions at Kiona

	2004	2005	2006	2007
% of time threshold value not met, Apr. thru Sept.				
DO < 8.0 mg/L	37	35	18	23
pH > 8.5	45	62	40	41
Temperature > 21 deg C	46	40	37	38
Turbidity > 10 FNU	2	2	47	36
# days with above-average flow, Mar. 1 - Jun. 30, out of 122 days	24	0	58	62
Median daily mean gage height (ft), Mar. 1 - Jun. 30	4.4	3.8	6.3	6.6
Peak flow (cfs) and month of occurrence	6,020 (Mar)	10,000 (Jan)	11,600 (May)	17,180 (Mar)
Average annual air temperature (º F)	56.6	57.6	53.9	56.1
Total annual rainfall (in)	5.4	4.6	5.4	5.4
Aquatic plant biomass, median dry weight (g/m2)	no data	1020	32	84